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AN ASCII FORTRAN SUBROUTINE FOR COMPUTING THE ELECTROMAGNETIC R--ETC(U)
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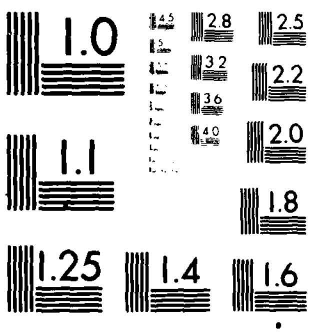

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the ASCMIE subroutine for performing Mie scattering calculations by means of the downward recursion algorithm developed by J. V. Dave. ASCMIE is written in UNIVAC 1100 series ASCII FORTRAN language. The ASCII FORTRAN compiler is a modern, state-of-the-art compiler which implements the ANSI FORTRAN 77 standard; this compiler is intended as a future replacement for the UNIVAC 1100 series FORTRAN V compiler. Rather than carry out a straightforward conversion of the FORTRAN V Mie scattering

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routine to ASCII FORTRAN, the code was completely rewritten in order to incorporate new ASCII FORTRAN language elements. The result is a more structured, modular, Mie scattering code which executes faster than the FORTRAN V code.

PREFACE

The work described in this report was authorized under Project 1L162662A554, Smoke/Obscurant Technology. This work was started and completed in May 1980.

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CONTENTS

AN ASCII FORTRAN SUBROUTINE FOR COMPUTING THE ELECTROMAGNETIC RADIATION SCATTERED BY A SPHERE

1 INTRODUCTION

The Lorenz-Mie formalism[1,2,3] is the analytical solution for the far field radiation which results when plane electromagnetic waves are scattered by a homogeneous spherical particle. With the advent of modern high speed computers programmed to provide numerical results, the Lorenz-Mie formalism may be regarded as an idealized experimental tool which is capable of predicting with certainty the scattering produced by spherical particulates.[3]

The development and use of computer codes to perform Lorenz-Mie calculations are of prime importance for smoke/aerosol research. For example, the excellent and widely used FORTRAN subroutine DBMIE,[4] which was developed by J. V. Dave,[5] has been the mainstay for performing such calculations at Chemical Systems Laboratory (CSL). The DBMIE code was modified for use on the ARRADCOM UNIVAC 1108 computer as a FORTRAN V subroutine.[6] The FORTRAN V compiler will be replaced in the near future by the UNIVAC 1100 series ASCII FORTRAN compiler.[7] The ASCII compiler is a modern, state-of-the-art compiler which implements the ANSI FORTRAN 77 standard.[8] Rather than carry out a straightforward conversion of the FORTRAN V Mie scattering subroutine, the code was completely rewritten to incorporate new ASCII FORTRAN language elements. The result was the ASCMIE subroutine which is a more structured, modular, Mie scattering code which executes faster than the FORTRAN V code.

2 SOFTWARE DESIGN AND CODING CONVENTIONS

A compilation listing of the ASCMIE subroutine is given in appendix A; the reader should become familiar with this listing before proceeding. This subroutine is an implementation of the downward recursion algorithm of Dave.[5] A call to subroutine ASCMIE requires the specification of the following input arguments:

X = $\pi D/\lambda$, the size parameter for a sphere of diameter D illuminated by electromagnetic radiation of wavelength λ. An error condition is generated and the execution of ASCMIE is halted if $X \leq 0$. X is a double precision variable.

N = the real part of the complex refractive index, m. A printed warning is generated if $N \leq 1$ because the algorithm has been thoroughly tested for $N > 1$ only. N is a double precision variable.

K = imaginary part of the complex refractive index, m. An error condition is generated and the execution of ASCMIE is halted if $K < 0$. K is a double precision variable.

THETAD = a double precision array containing the scattering angles in degrees. The maximum number of scattering angles is set by the PARAMETER variable MXTHET at 100 angles. An error condition is generated and the execution of ASCMIE is halted if any value of the scattering angle exceeds 90 degrees.

NTHETA = the number of scattering angles at which the Lorenz-Mie solutions are sought. NTHETA should not exceed 100 unless ASCMIE is recompiled with MXTHET set larger. An error condition is generated and the execution of ASCMIE is halted if NTHETA > MXTHET. NTHETA is an integer variable.

All the input arguments specified above are checked for error and warning conditions before a decision is made to proceed or halt execution. Each error or warning is described by a printed message. Also, a check is made to determine if sufficient array storage is available to perform the calculations before the program is allowed to proceed.

The subroutine returns the following outputs:

QEXT = efficiency factor for total extinction. QEXT is a double precision variable.

QSCAT = efficiency factor for scattering. QSCAT is a double precision variable.

CTBRQS = product of the asymmetry factor and QSCAT. CTBRQS is a double precision variable.

FMX = elements of the transformation matrix. FMX (4,MXTHET,2) is a double precision array.

Definitions of the efficiency factors, asymmetry factor, and the transformation matrix can be found in any of several excellent treatises on the Lorenz-Mie Theroy.[1,2,3]

An attempt was made to make the ASCMIE code as structured as possible. The beginning of this program module is indicated by the SUBROUTINE statement and the program module ends with the END statement. All of the FORTRAN code which implements the algorithm between the SUBROUTINE and END statements was divided into blocks according to the following scheme:

(a) BLOCK 0 contains all specifications statements.

(b) BLOCKS 100 to 600 are blocks of FORTRAN code which implement algorithmic tasks.

(c) Each BLOCK is divided into as many SUBBLOCKS as necessary for clarity and convenience.

Each BLOCK of the code was constructed according to the following style rules:

(a) Each BLOCK starts with a statement labelled:

0, 100, 200, . . ., 600

(b) Each SUBBLOCK starts with a statement labelled:

```
  0, 10, 20, . . ., 90
100,110,120, . . .,190
200,210,220, . . .,290
  .   .   .  . . .  .
  .   .   .  . . .  .
  .   .   .  . . .  .
600,610,620, . . .,690
```

The smallest available label is used.

(c) 9000 series labels are FORMAT statements. Each digit following the 9 serves to identify the BLOCK and SUBBLOCK in which the FORMAT statement occurs.

Using the conventions described above, the ASCMIE code is represented by the following skeleton:

```
START OF MODULE:  SUBROUTINE ASCMIE (X, N, K,
THETAD, NTHETA, QEXT, QSCAT, CTBRQS, FMX)

     BLOCK 0:    SPECIFICATIONS
     BLOCK 100:  CHECK FOR INVALID OR
                 OUT-OF-RANGE ARGUMENTS
     BLOCK 200:  INITIALIZING CALCULATIONS
     BLOCK 300:  SERIES SUMMATIONS
     BLOCK 400:  CALCULATE FINAL RESULTS
     BLOCK 500:  RETURN
     BLOCK 600:  ERROR SECTION
END OF MODULE:  END
```

3 RESULTS

3.1 Sample Problem. A FORTRAN main program, MIECHK, was written to call the ASCMIE subroutine and produce numeric results for sample problems. MIECHK is essentially the same program as that used previously by Dave[5] for the same purpose; a compilation listing of program MIECHK is given in appendix B. A MAP (Memory Allocation Processor) listing of the absolute element ASCMIE, which was produced by including MIECHK and ASCMIE, is given in appendix C. This absolute element was executed for Dave's sample problem $m = 1.342 - 0.1i$, $X = 1571.0$.[5] The results produced by ASCMIE are given in appendix D and are in agreement with previous results.[5]

3.2 Timing Study. An important consideration in choosing a Mie scattering code is the computer time required to produce numeric results. The time required to execute ASCMIE for the sample problem described above (section 3.1) was compared as the size parameter was varied from 0.1 to 1571 with similar results for two FORTRAN V versions of the Dave subroutine - MEMIE* and MIE2.** The results of the timing study are presented in table 1, where the times shown are the central processing unit times as listed by the UNIVAC 1108 accounting algorithm.

Table 1. Comparison of Execution Times for Three Mie Scattering Subroutines

X	Time		
	ASCMIE	MEMIE	MIE2
	sec	sec	sec
0.1	.947	.979	.995
1.0	1.018	1.049	1.051
10.0	1.427	1.490	1.592
100.0	4.021	4.068	5.004
1000.0	27.758	28.952	34.671
1571.0	41.166	42.137	51.637

In every case ASCMIE took less time to compute the same results than the MEMIE and MIE2 subroutines. Independent of the value of X, we find that

$$T_A < T_{M1} < T_{M2} \tag{1}$$

where

T_A = time required when using the ASCMIE subroutine

T_{M1} = time required when using the MEMIE subroutine

T_{M2} = time required when using the MIE2 subroutine

Because of the uncertainties inherent in computer timing operations and the cursory nature of this timing study, these results should be regarded as suggestive but not definitive.

*Unpublished data by M. E. Milham.
**Unpublish d data by . H. Frickel.

4. CONCLUSIONS

The ASCMIE subroutine:

(a) Is based on the downward recursion scheme of Dave.

(b) Uses many of the FORTRAN 77 features available in the UNIVAC 1100 series ASCII FORTRAN language.

(c) Is more modular and structured than the original Dave code.

(d) Executes faster than FORTRAN V versions of the Dave code (MEMIE, MIE2).

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APPENDIX A

FTN COMPILATION LISTING OF SUBROUTINE ASCMIE

```
@FTN.DRSZ ASCM
FTN 8R1  *02/12/81-09:42(0.)
      C-----------------------------------------------------------------  . ASCM0001
      C                                                                   . ASCM0002
            SUBROUTINE ASCMIE(X.N.K.THETAD.NTHETA.QEXT.QSCAT.CTBRQS.FMX)  . ASCM0003
      C                                                                   . ASCM0004
      *** M. E. MILHAM         1980                                       . ASCM0005
      C                                                                   . ASCM0006
      C INPUTS:                                                           . ASCM0007
      C     X = SIZE PARAMETER.PI*D/WL                                    . ASCM0008
      C     N = REAL PART OF REFRACTIVE INDEX                             . ASCM0009
      C     K = IMAGINARY PART OF REFRACTIVE INDEX                        . ASCM0010
      C     THETAD = SCATTERING ANGLES(DEGREES)                           . ASCM0011
      C     NTHETA = NUMBER OF SCATTERING ANGLES                          . ASCM0012
      C OUTPUTS:                                                          . ASCM0013
      C     QEXT = EFFICIENCY FACTOR FOR EXTINCTION                       . ASCM0014
      C     QSCAT = EFFICIENCY FACTOR FOR SCATTERING                      . ASCM0015
      C     CTBRQS = ASYMMETRY FACTOR * QSCAT                             . ASCM0016
      C     FMX = ELEMENTS OF THE TRANSFORMATION MATRIX(F)                . ASCM0017
      C                                                                   . ASCM0018
      C                                                                   . ASCM0019
      C                                                                   . ASCM0020
      C-------------------------------------------------------------      . ASCM0021
      C BLOCK 0: ASCMIE SPECIFICATIONS                                    . ASCM0022
                                                                          . ASCM0023
      00    PARAMETER                                                     . ASCM0024
          +             MXTHET=100.                                       . ASCM0025
          +             NMX0=7000.                                        . ASCM0026
          +             AMAX=NMX0-1.                                      . ASCM0027
          +             RAD=DATAN(1.0D0)/45.0D0                           . ASCM0028
      C                                                                   . ASCM0029
                                                                          . ASCM0030
      10    LOGICAL                                                       . ASCM0031
          +         STOP.                                                 . ASCM0032
          +         ENDSUM                                                . ASCM0033
      C                                                                   . ASCM0034
                                                                          . ASCM0035
      20    REAL*8                                                        . ASCM0036
          +        X.                                                     . ASCM0037
          +        XI.                                                    . ASCM0038
          +        N.                                                     . ASCM0039
          +        K.                                                     . ASCM0040
          +        QEXT.                                                  . ASCM0041
          +        QSCAT.                                                 . ASCM0042
          +        T(5).                                                  . ASCM0043
          +        TA(4).                                                 . ASCM0044
          +        TB(2).                                                 . ASCM0045
          +        TC(2)                                                  . ASCM0046
      C                                                                   . ASCM0047
            REAL*8                                                        . ASCM0048
          +        TD(2).                                                 . ASCM0049
          +        TE(2).                                                 . ASCM0050
          +        CTBRQS.                                                . ASCM0051
          +        FMX(4.MXTHET.2).                                       . ASCM0052
          +        PI(3.MXTHET).                                          . ASCM0053
```

```
     +       TAU(3,MXTHET),                                             . ASCM0054
     +       CSTHET(MXTHET),                                            . ASCM0055
     +       SI2THT(MXTHET),                                            . ASCM0056
     +       THETAD(MXTHET)                                             . ASCM0057
C                                                                       . ASCM0058
                                                                        . ASCM0059
30    COMPLEX*16                                                        . ASCM0060
     +            M,                                                    . ASCM0061
     +            MI,                                                   . ASCM0062
     +            XMI,                                                  . ASCM0063
     +            AN,                                                   . ASCM0064
     +            BN,                                                   . ASCM0065
     +            ANP,                                                  . ASCM0066
     +            BNP,                                                  . ASCM0067
     +            TC1,                                                  . ASCM0068
     +            TC2,                                                  . ASCM0069
     +            WM1,                                                  . ASCM0070
     +            WN(2),                                                . ASCM0071
     +            A(NMXO)                                               . ASCM0072
C                                                                       . ASCM0073
                                                                        . ASCM0074
40    EQUIVALENCE                                                       . ASCM0075
     +             (WN(1),TA(1)),                                       . ASCM0076
     +             (AN,TB(1)),                                          . ASCM0077
     +             (BN,TC(1)),                                          . ASCM0078
     +             (ANP,TD(1)),                                         . ASCM0079
     +             (BNP,TE(1))                                          . ASCM0080
C                                                                       . ASCM0081
C END OF BLOCK 0: ASCMIE                                                . ASCM0082
C                                                                       . ASCM0083
C-----------------------------------------------------------------      . ASCM0084
C   BLOCK 100: ASCMIE CHECK FOR INVALID OR OUT OF RANGE ARGUMENTS       . ASCM0085
C                                                                       . ASCM0086
C CHECK FOR X>0                                                         . ASCM0087
                                                                        . ASCM0088
100   STOP=.FALSE.                                                      . ASCM0089
      IF(X.GT.0.0D0) THEN                                               . ASCM0090
         CONTINUE                                                       . ASCM0091
C                                                                       . ASCM0092
                         ELSE                                           . ASCM0093
C                                                                       . ASCM0094
         WRITE(UNIT=6,FMT=9100) X                                       . ASCM0095
 9100    FORMAT(' X = ',G15.7,' MUST BE GREATER THAN 0')                . ASCM0096
C                                                                       . ASCM0097
      STOP=.TRUE.                                                       . ASCM0098
C                                                                       . ASCM0099
      END IF                                                            . ASCM0100
C                                                                       . ASCM0101
C CHECK N>1                                                             . ASCM0102
                                                                        . ASCM0103
110   IF(N.GT.1.D0) THEN                                                . ASCM0104
         CONTINUE                                                       . ASCM0105
C                                                                       . ASCM0106
                        ELSE                                            . ASCM0107
         WRITE(UNIT=6,FMT=9110) N                                       . ASCM0108
 9110    FORMAT(' N = ',G15.7,' SUBROUTINE NOT CHECKED FOR N<1')        . ASCM0109
      END IF                                                            . ASCM0110
C                                                                       . ASCM0111
```

```
1      C CHECK K
1
       120   IF(K.LT.0.0D0) THEN
1               WRITE(UNIT=6,FMT=9120) K
1       9120    FORMAT(' K =',G15.7,' K MUST BE .GE.0')
1      C
1            STOP=.TRUE.
1      C
1                                  ELSE
1               CONTINUE
1            END IF
1      C
1      C CHECK NTHETA
1
       130   IF(NTHETA.LE.MXTHET.AND.NTHETA.GT.0) THEN
1               CONTINUE
1      C
1                                                        ELSE
1               I=MXTHET
1               WRITE(UNIT=6,FMT=9130) NTHETA,I
1       9130    FORMAT(' CALCULATIONS REQUESTED FOR AN IMPROPER NUMBER OF'
1          +          ' SCATTERING ANGLES. NTHETA =',I10/' MXTHET =',I10)
1      C
1            STOP=.TRUE.
1      C
1            END IF
1      C
1      C CHECK THETAD(J)
1
       140   DO 141 J=1,NTHETA
       C REMOVE ANY NEGATIVE ANGLES
1            THETAD(J)=DABS(THETAD(J))
1      C
1            IF(THETAD(J).GT.90.0D0) THEN
2               WRITE(UNIT=6,FMT=9140) J,THETAD(J)
2       9140    FORMAT(' THETAD(',I3,') =',G15.4,' DEGREES.THETAD MUST'
2          +             ,' BE .LE.90.')
2      C
2            STOP=.TRUE.
2      C
2                                     ELSE
2               CONTINUE
2            END IF
1        141 CONTINUE
1      C
1      C SET NMX1,NMX2 AND CHECK "A" ARRAY STORAGE
1
       150   T(1)=(X*X)*(N*N+K*K)
             T(1)=DSQRT(T(1))
             NMX1=1.1D0*T(1)
             NMX2=T(1)
       C
             IF(NMX1.LE.AMAX.AND.NMX1.GE.150) THEN
1               ELSE IF(NMX1.LT.150) THEN
1                       NMX1=150
1                       NMX2=135
1      C
1                                     ELSE
```

```
1          I=AMAX                                                    . ASCM0170
1          WRITE(UNIT=6,FMT=9150) NMX1,I                             . ASCM0171
1    9150  FORMAT(' A(',I5,') REQUIRED ONLY A(',I5,') IS AVAILABLE')  . ASCM0172
1          WRITE(UNIT=6,FMT=9151) X,N,K                              . ASCM0173
1    9151  FORMAT(' X =',G15.7,' N =',G15.7,' K =',G15.7)            . ASCM0174
1       C                                                            . ASCM0175
1          STOP=.TRUE.                                               . ASCM0176
1          END IF                                                    . ASCM0177
1       C                                                            . ASCM0178
1       C STOP OR GO ???                                             . ASCM0179
1                                                                    . ASCM0180
     160   IF(STOP) THEN                                             . ASCM0181
1            STOP                                                    . ASCM0182
1       C                                                            . ASCM0183
1                  ELSE                                              . ASCM0184
1            CONTINUE                                                . ASCM0185
1          END IF                                                    . ASCM0186
1       C                                                            . ASCM0187
1       C END OF BLOCK 100: ASCMIE                                   . ASCM0188
1       C                                                            . ASCM0189
1       C------------------------------------------------------------ . ASCM0190
1       C BLOCK 200: ASCMIE INITIALIZING CALCULATIONS                 . ASCM0191
1       C                                                            . ASCM0192
1       C SET: A                                                     . ASCM0193
1                                                                    . ASCM0194
     200   M=DCMPLX(N,-K)                                            . ASCM0195
           MI=1.0D0/M                                                . ASCM0196
           XI=1.0D0/X                                                . ASCM0197
           XMI=XI*MI                                                 . ASCM0198
        C                                                            . ASCM0199
           NN1=NMX1+1                                                . ASCM0200
           A(NN1)=(0.0D0,0.0D0)                                      . ASCM0201
        C                                                            . ASCM0202
           DO 201 NN=NN1,2,-1                                        . ASCM0203
1          A(NN-1)=NN*XMI-1.0D0/(NN*XMI+A(NN))                       . ASCM0204
1      201 CONTINUE                                                  . ASCM0205
1       C                                                            . ASCM0206
1       C SET PHASE FUNCTIONS(PI,TAU)                                . ASCM0207
1                                                                    . ASCM0208
     210   DO 211 J=1,NTHETA                                         . ASCM0209
        C                                                            . ASCM0210
1          IF(THETAD(J).EQ.0.0D0) THEN                               . ASCM0211
2            CSTHET(J)=1.0D0                                         . ASCM0212
2            SI2THT(J)=0.0D0                                         . ASCM0213
2               ELSE IF(THETAD(J).EQ.90.0D0) THEN                    . ASCM0214
2            CSTHET(J)=0.0D0                                         . ASCM0215
2            SI2THT(J)=1.0D0                                         . ASCM0216
2       C                                                            . ASCM0217
2                              ELSE                                  . ASCM0218
2            CSTHET(J)=DCOS(RAD*THETAD(J))                           . ASCM0219
2            SI2THT(J)=1.0D0-CSTHET(J)*CSTHET(J)                     . ASCM0220
2          END IF                                                    . ASCM0221
2       C                                                            . ASCM0222
1      211 CONTINUE                                                  . ASCM0223
1       C                                                            . ASCM0224
           DO 212 J=1,NTHETA                                         . ASCM0225
        C                                                            . ASCM0226
1          PI(1,J)=0.0D0                                             . ASCM0227
```

```
      PI(2,J)=1.0D0
C
      TAU(1,J)=0.0D0
      TAU(2,J)=CSTHET(J)
C
  212 CONTINUE
C
C SET: W FUNCTION,AN,BN,ANP,BNP

220   T(1)=DCOS(X)
      T(2)=DSIN(X)
      WM1=DCMPLX(T(1),-T(2))
      WN(1)=DCMPLX(T(2),T(1))
      WN(2)=XI*WN(1)-WM1
C
      TC1=A(1)*MI+XI
      TC2=A(1)*M+XI
      AN=(TC1*TA(3)-TA(1))/(TC1*WN(2)-WN(1))
      BN=(TC2*TA(3)-TA(1))/(TC2*WN(2)-WN(1))
      ANP=AN
      BNP=BN
C
C SET: COMPLEX AMPLITUDES(S1,S2)
C FOR BLOCKS 200 - 300:
C FMX(1,J,K)=REAL PART OF S1
C FMX(2,J,K)=IMAGINARY PART OF S1
C FMX(3,J,K)=REAL PART OF S2
C FMX(4,J,K)=IMAGINARY PART OF S2
C KK=1:FOR THETAD(J),KK=2 FOR 180.0-THETAD(J)

230   T(1)=1.50D0
      TB(1)=T(1)*TB(1)
      TB(2)=T(1)*TB(2)
      TC(1)=T(1)*TC(1)
      TC(2)=T(1)*TC(2)
C
      DO 231 J=1,NTHETA
C
      T(5)=TAU(2,J)
C
      T(1)=TC(1)*T(5)
      T(2)=TC(2)*T(5)
      T(3)=TB(1)*T(5)
      T(4)=TB(2)*T(5)
C
      T(5)=PI(2,J)
C
      FMX(1,J,1)=TB(1)*T(5)
      FMX(1,J,2)=FMX(1,J,1)
      FMX(1,J,1)=FMX(1,J,1)+T(1)
      FMX(1,J,2)=FMX(1,J,2)-T(1)
C
      FMX(2,J,1)=TB(2)*T(5)
      FMX(2,J,2)=FMX(2,J,1)
      FMX(2,J,1)=FMX(2,J,1)+T(2)
      FMX(2,J,2)=FMX(2,J,2)-T(2)
C
      FMX(3,J,1)=TC(1)*T(5)
```

```
      FMX(3,J,2)=FMX(3,J,1)                                              . ASCM0286
      FMX(3,J,1)=FMX(3,J,1)+T(3)                                         . ASCM0287
      FMX(3,J,2)=FMX(3,J,2)-T(3)                                         . ASCM0288
C                                                                        . ASCM0289
      FMX(4,J,1)=TC(2)*T(5)                                              . ASCM0290
      FMX(4,J,2)=FMX(4,J,1)                                              . ASCM0291
      FMX(4,J,1)=FMX(4,J,1)+T(4)                                         . ASCM0292
      FMX(4,J,2)=FMX(4,J,2)-T(4)                                         . ASCM0293
C                                                                        . ASCM0294
  231 CONTINUE                                                           . ASCM0295
C                                                                        . ASCM0296
C SET QEXT,QSCAT, AND CTBRQS                                             . ASCM0297
                                                                         . ASCM0298
240   QEXT=2.0D0*(TB(1)+TC(1))                                           . ASCM0299
      QSCAT=(TB(1)**2+TB(2)**2+TC(1)**2+TC(2)**2)/0.75D0                 . ASCM0300
      CTBRQS=0.0D0                                                       . ASCM0301
C                                                                        . ASCM0302
C END OF BLOCK 200: ASCMIE                                               . ASCM0303
C                                                                        . ASCM0304
C----------------------------------------------------------------------- . ASCM0305
C BLOCK 300: ASCMIE SERIES SUMMATIONS                                    . ASCM0306
C                                                                        . ASCM0307
                                                                         . ASCM0308
300   DO 510 NN=2,NMX2                                                   . ASCM0309
* NOTE THIS DO LOOP TERMINATES IN BLOCK 500                              . ASCM0310
C                                                                        . ASCM0311
      T(1)=2*NN-1                                                        . ASCM0312
      T(2)=NN-1                                                          . ASCM0313
      T(3)=2*NN+1                                                        . ASCM0314
C                                                                        . ASCM0315
      DO 302 J=1,NTHETA                                                  . ASCM0316
      PI(3,J)=(T(1)*PI(2,J)*CSTHET(J)-NN*PI(1,J))/T(2)                   . ASCM0317
      TAU(3,J)=CSTHET(J)*(PI(3,J)-PI(1,J))-T(1)*SI2THT(J)*PI(2,J)+       . ASCM0318
     +                                               TAU(1,J)            . ASCM0319
  302 CONTINUE                                                           . ASCM0320
C                                                                        . ASCM0321
C SET :W'S,AN,BN                                                         . ASCM0322
                                                                         . ASCM0323
310   WM1=WN(1)                                                          . ASCM0324
      WN(1)=WN(2)                                                        . ASCM0325
      WN(2)=T(1)*XI*WN(1)-WM1                                            . ASCM0326
C                                                                        . ASCM0327
      TC1=A(NN)*MI+NN*XI                                                 . ASCM0328
      TC2=A(NN)*M+NN*XI                                                  . ASCM0329
      AN=(TC1*TA(3)-TA(1))/(TC1*WN(2)-WN(1))                             . ASCM0330
      BN=(TC2*TA(3)-TA(1))/(TC2*WN(2)-WN(1))                             . ASCM0331
C                                                                        . ASCM0332
C SET QEXT,QSCAT,CTBRQS                                                  . ASCM0333
                                                                         . ASCM0334
320   T(5)=NN                                                            . ASCM0335
      T(4)=T(1)/(T(2)*T(5))                                              . ASCM0336
      T(2)=(T(2)*(T(5)+1.0D0))/T(5)                                      . ASCM0337
C                                                                        . ASCM0338
      CTBRQS=CTBRQS+T(2)*(TD(1)*TB(1)+TD(2)*TB(2)+TE(1)*TC(1)+           . ASCM0339
     +TE(2)*TC(2))+T(4)*(TD(1)*TE(1)+TD(2)*TE(2))                        . ASCM0340
      QEXT=QEXT+T(3)*(TB(1)+TC(1))                                       . ASCM0341
      T(4)=TB(1)**2+TB(2)**2+TC(1)**2+TC(2)**2                           . ASCM0342
      QSCAT=QSCAT+T(3)*T(4)                                              . ASCM0343
```

```
1    C                                                                   . ASCM0344
1    C SET COMPLEX AMPLITUDES                                            . ASCM0345
1                                                                        . ASCM0346
1    330    T(2)=NN*(NN+1)                                               . ASCM0347
1           T(1)=T(3)/T(2)                                               . ASCM0348
1           KK=(NN/2)*2                                                  . ASCM0349
1    C                                                                   . ASCM0350
1           DO 331 J=1,NTHETA                                            . ASCM0351
1    C                                                                   . ASCM0352
2           FMX(1,J,1)=FMX(1,J,1)+T(1)*(TB(1)*PI(3,J)+TC(1)*TAU(3,J))    . ASCM0353
2           FMX(2,J,1)=FMX(2,J,1)+T(1)*(TB(2)*PI(3,J)+TC(2)*TAU(3,J))    . ASCM0354
2           FMX(3,J,1)=FMX(3,J,1)+T(1)*(TC(1)*PI(3,J)+TB(1)*TAU(3,J))    . ASCM0355
2           FMX(4,J,1)=FMX(4,J,1)+T(1)*(TC(2)*PI(3,J)+TB(2)*TAU(3,J))    . ASCM0356
2    C                                                                   . ASCM0357
2           IF(KK.NE.NN) THEN                                            . ASCM0358
2    C                                                                   . ASCM0359
3           FMX(1,J,2)=FMX(1,J,2)+T(1)*(TB(1)*PI(3,J)-TC(1)*TAU(3,J))    . ASCM0360
3           FMX(2,J,2)=FMX(2,J,2)+T(1)*(TB(2)*PI(3,J)-TC(2)*TAU(3,J))    . ASCM0361
3           FMX(3,J,2)=FMX(3,J,2)+T(1)*(TC(1)*PI(3,J)-TB(1)*TAU(3,J))    . ASCM0362
3           FMX(4,J,2)=FMX(4,J,2)+T(1)*(TC(2)*PI(3,J)-TB(2)*TAU(3,J))    . ASCM0363
3    C                                                                   . ASCM0364
3                       ELSE                                             . ASCM0365
3    C                                                                   . ASCM0366
3           FMX(1,J,2)=FMX(1,J,2)+T(1)*(-TB(1)*PI(3,J)+TC(1)*TAU(3,J))   . ASCM0367
3           FMX(2,J,2)=FMX(2,J,2)+T(1)*(-TB(2)*PI(3,J)+TC(2)*TAU(3,J))   . ASCM0368
3           FMX(3,J,2)=FMX(3,J,2)+T(1)*(-TC(1)*PI(3,J)+TB(1)*TAU(3,J))   . ASCM0369
3           FMX(4,J,2)=FMX(4,J,2)+T(1)*(-TC(2)*PI(3,J)+TB(2)*TAU(3,J))   . ASCM0370
3    C                                                                   . ASCM0371
3           END IF                                                       . ASCM0372
3    C                                                                   . ASCM0373
2      331 CONTINUE                                                      . ASCM0374
2    C                                                                   . ASCM0375
2    C CHECK FOR CONVERGENCE                                             . ASCM0376
2                                                                        . ASCM0377
1    340    ENDSUM=T(4).LT.1.0D-14                                       . ASCM0378
1           IF(.NOT.ENDSUM)  THEN                                        . ASCM0379
1    * NOTE THIS IF THEN-ELSE ENDS IN BLOCK 500                          . ASCM0380
1    C                                                                   . ASCM0381
1    C UPDATE PI,TAU,ANP,BNP FOR NEXT ITERATION                          . ASCM0382
1                                                                        . ASCM0383
2    350    DO 351 J=1,NTHETA                                            . ASCM0384
2    C                                                                   . ASCM0385
3           PI(1,J)=PI(2,J)                                              . ASCM0386
3           PI(2,J)=PI(3,J)                                              . ASCM0387
3    C                                                                   . ASCM0388
3           TAU(1,J)=TAU(2,J)                                            . ASCM0389
3           TAU(2,J)=TAU(3,J)                                            . ASCM0390
3    C                                                                   . ASCM0391
3      351 CONTINUE                                                      . ASCM0392
3    C                                                                   . ASCM0393
2           ANP=AN                                                       . ASCM0394
2           BNP=BN                                                       . ASCM0395
2    C                                                                   . ASCM0396
2    C END OF BLOCK 300: ASCMIE                                          . ASCM0397
2    C BLOCK 400: ASCMIE CALCULATE FINAL RESULTS                         . ASCM0398
2    C-----------------------------------------------------------        . ASCM0399
2    C                       SUMMATION COMPLETE                          . ASCM0400
2    C-----------------------------------------------------------        . ASCM0401
```

```
2   C                                                                  . ASCM0402
2   C------------------------------------------------------------------ . ASCM0403
2                                                                      . ASCM0404
2                                     ELSE                             . ASCM0405
2   400   DO 402 J=1,NTHETA                                            . ASCM0406
3         DO 402 KK=1,2                                                . ASCM0407
3   C                                                                  . ASCM0408
4         DO 401 I=1,4                                                 . ASCM0409
5         T(I)=FMX(I,J,KK)                                             . ASCM0410
5     401 CONTINUE                                                     . ASCM0411
5   C                                                                  . ASCM0412
5   C SET F MATRIX ELEMENTS                                            . ASCM0413
5   C                                                                  . ASCM0414
4         FMX(1,J,KK)=T(3)**2+T(4)**2                                  . ASCM0415
4         FMX(2,J,KK)=T(1)**2+T(2)**2                                  . ASCM0416
4         FMX(3,J,KK)=T(1)*T(3)+T(2)*T(4)                              . ASCM0417
4         FMX(4,J,KK)=T(2)*T(3)-T(4)*T(1)                              . ASCM0418
4   C                                                                  . ASCM0419
4     402 CONTINUE                                                     . ASCM0420
4   C                                                                  . ASCM0421
4   C SET QEXT,QSCAT,CTBRQS                                            . ASCM0422
4                                                                      . ASCM0423
2   410   T(1)=2.0D0*XI**2                                             . ASCM0424
2         QEXT=QEXT*T(1)                                               . ASCM0425
2         QSCAT=QSCAT*T(1)                                             . ASCM0426
2         CTBRQS=2.0D0*CTBRQS*T(1)                                     . ASCM0427
2   C                                                                  . ASCM0428
2   C END OF BLOCK 400: ASCMIE                                         . ASCM0429
2   C                                                                  . ASCM0430
2   C------------------------------------------------------------------ . ASCM0431
2   C BLOCK 500: ASCMIE RETURN                                         . ASCM0432
2                                                                      . ASCM0433
2   500   RETURN                                                       . ASCM0434
2   C                                                                  . ASCM0435
2   C                                                                  . ASCM0436
2   C-------------------------------------------------------------     . ASCM0437
2         END IF                                                       . ASCM0438
2   C                                                                  . ASCM0439
1   510   CONTINUE                                                     . ASCM0440
1   C                                                                  . ASCM0441
1   C END OF BLOCK 500: ASCMIE                                         . ASCM0442
1   C                                                                  . ASCM0443
1   C BLOCK 600: ASCMIE ERROR SECTION - CONVERGENCE NOT OBTAINED       . ASCM0444
1                                                                      . ASCM0445
    600   WRITE(UNIT=6,FMT=9600) NMX2                                  . ASCM0446
     9600 FORMAT(' NMX2 =',I10,' IS TOO SMALL. CONVERGENCE'            . ASCM0447
        +                      ' WAS NOT OBTAINED')                    . ASCM0448
          STOP                                                         . ASCM0449
    C                                                                  . ASCM0450
    C END OF BLOCK 600: ASCMIE                                         . ASCM0451
                                                                       . ASCM0452
          END                                                          . ASCM0453
```

F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G

SUBROUTINE ASCMIE

NAME	USE	LINE NUMBER	
100	DEFINED	89	
110	DEFINED	104	
120	DEFINED	114	
130	DEFINED	126	
140	DEFINED	141	
141	DEFINED	155	
	USED	141	
150	DEFINED	159	
160	DEFINED	181	
200	DEFINED	195	
201	DEFINED	205	
	USED	203	
210	DEFINED	209	
211	DEFINED	223	
	USED	209	
212	DEFINED	233	
	USED	225	
220	DEFINED	237	
230	DEFINED	258	
231	DEFINED	295	
	USED	264	
240	DEFINED	299	
300	DEFINED	309	
302	DEFINED	320	
	USED	316	
310	DEFINED	324	
320	DEFINED	335	
330	DEFINED	347	
331	DEFINED	374	
	USED	351	
340	DEFINED	378	
350	DEFINED	384	
351	DEFINED	392	
	USED	384	
400	DEFINED	406	
401	DEFINED	411	
	USED	409	
402	DEFINED	420	
	USED	406	407
410	DEFINED	424	
500	DEFINED	434	
510	DEFINED	440	
	USED	309	
600	DEFINED	446	
9100	DEFINED	96	
	USED	95	
9110	DEFINED	109	
	USED	108	
9120	DEFINED	116	
	USED	115	
9130	DEFINED	132	
	USED	131	

9140	DEFINED	147							
	USED	146							
9150	DEFINED	172							
	USED	171							
9151	DEFINED	174							
	USED	173							
9600	DEFINED	447							
	USED	446							
A	SPEC	60							
	SET	201	204						
	USED	204	243	244	328	329			
AMAX	SET	24							
	USED	164	170						
AN	EQUIV	75							
	SPEC	60							
	SET	245	330						
	USED	247	394						
ANP	EQUIV	75							
	SPEC	60							
	SET	247	394						
ASCMIE	SPEC	3							
BN	EQUIV	75							
	SPEC	60							
	SET	246	331						
	USED	248	395						
BNP	EQUIV	75							
	SPEC	60							
	SET	248	395						
CSTHET	SPEC	48							
	SET	212	215	219					
	USED	220	220	231	317	318			
CTBRQS	SPEC	3	48						
	SET	301	339	427					
	USED	339	427						
DCOS	USED	219	237						
	[illegible]	[illegible]							
DSQRT	USED	160							
ENDSUM	SPEC	31							
	SET	378							
	USED	379							
FMX	SPEC	3	48						
	SET	275	276	277	278	280	281	282	283
		285	286	287	288	290	291	292	293
		353	354	355	356	360	361	362	363
		367	368	369	370	415	416	417	418
	USED	276	277	278	281	282	283	286	287
		288	291	292	293	353	354	355	356
		360	361	362	363	367	368	369	370
		410							
I	SET	130	170	409	409				
	USED	131	171	410	410				
J	SET	141	141	209	209	225	225	264	264
		316	316	351	351	384	384	406	406
	USED	143	143	145	146	146	211	212	213
		214	215	216	219	219	220	220	220
		227	228	230	231	231	266	273	275
		276	276	277	277	278	278	280	281
		281	282	282	283	283	285	286	286

		287	287	288	288	290	291	291	292
		292	293	293	317	317	317	317	318
		318	318	318	318	318	318	353	353
		353	353	354	354	354	354	355	355
		355	355	356	356	356	356	360	360
		360	360	361	361	361	361	362	362
		362	362	363	363	363	363	367	367
		367	367	368	368	368	368	369	369
		369	369	370	370	370	370	386	386
		387	387	389	389	390	390	410	415
		416	417	418					
K	SPEC	3	36						
	USED	114	115	159	159	173	195		
KK	SET	349	407	407					
	USED	358	410	415	416	417	418		
M	SPEC	60							
	SET	195							
	USED	196	244	329					
MI	SPEC	60							
	SET	196							
	USED	198	243	328					
MXTHET	SET	24							
	USED	48	48	48	48	48	48	126	130
N	SPEC	3	36						
	USED	104	108	159	159	173	195		
NMX0	SET	24							
	USED	24	60						
NMX1	SET	161	166						
	USED	164	164	165	171	200			
NMX2	SET	162	167						
	USED	309	446						
NN	SET	203	203	309	309				
	USED	204	204	204	204	312	313	314	317
		328	328	329	329	335	347	347	349
		358							
NN1	SET	200							
	USED	201	203	203					
NTHETA	SPEC	3							
	USED	126	126	131	141	209	225	264	316
		351	384	406					
PI	SPEC	48							
	SET	227	228	317	386	387			
	USED	273	317	317	318	318	318	353	354
		355	356	360	361	362	363	367	368
		369	370	386	387				
QEXT	SPEC	3	36						
	SET	299	341	425					
	USED	341	425						
QSCAT	SPEC	3	36						
	SET	300	343	426					
	USED	343	426						
RAD	SET	24							
	USED	219							
SI2THT	SPEC	48							
	SET	213	216	220					
	USED	318							
STOP	SPEC	31							
	SET	89	98	118	135	150	176		

	USED	181							
I	SPEC	36							
	SET	159	160	237	238	258	266	268	269
		270	271	273	312	313	314	335	336
		337	342	347	348	410	424		
	USED	160	161	162	239	239	240	240	259
		260	261	262	268	269	270	271	275
		277	278	280	282	283	285	287	288
		290	292	293	317	317	318	326	336
		336	336	337	337	337	339	339	341
		343	343	348	348	353	354	355	356
		360	361	362	363	367	368	369	370
		378	415	415	416	416	417	417	417
		417	418	418	418	418	425	426	427
TA	EQUIV	75							
	SPEC	36							
	USED	245	245	246	246	330	330	331	331
TAU	SPEC	48							
	SET	230	231	318	389	390			
	USED	266	318	353	354	355	356	360	361
		362	363	367	368	369	370	389	390
TB	EQUIV	75							
	SPEC	36							
	SET	259	260						
	USED	259	260	270	271	275	280	299	300
		300	339	339	341	342	342	353	354
		355	356	360	361	362	363	367	368
		369	370						
TC	EQUIV	75							
	SPEC	36							
	SET	261	262						
	USED	261	262	268	269	285	290	299	300
		300	339	339	341	342	342	353	354
		355	356	360	361	362	363	367	368
		369	370						
TC1	SPEC	60							
	SET	243	328						
	USED	245	245	330	330				
TC2	SPEC	60							
	SET	244	329						
	USED	246	246	331	331				
TD	EQUIV	75							
	SPEC	48							
	USED	339	339	339	339				
TE	EQUIV	75							
	SPEC	48							
	USED	339	339	339	339				
THETAD	SPEC	3	48						
	SET	143							
	USED	143	145	146	211	214	219		
WM1	SPEC	60							
	SET	239	324						
	USED	241	326						
WN	EQUIV	75							
	SPEC	60							
	SET	240	241	325	326				
	USED	241	245	245	246	246	324	325	326
		330	330	331	331				

X	SPEC	3	36						
	USED	90	95	159	159	173	197	237	238
XI	SPEC	36							
	SET	197							
	USED	198	241	243	244	326	328	329	424
XMI	SPEC	60							
	SET	198							
	USED	204	204						

F O R T R A N   S T O R A G E   M A P

NAME	TYPE	MODE	RELATIVE ADDRESS	LOC COUNT	ELEMENT LENGTH	NUMBER OF ELEMENTS	COMMON SIZE	PROGRAM UNIT
100L	USRDEFND	STMTNMBR	000042	1				SUBROUTINE ASCMIE
110L	USRDEFND	STMTNMBR	000054	1				SUBROUTINE ASCMIE
120L	USRDEFND	STMTNMBR	000063	1				SUBROUTINE ASCMIE
130L	USRDEFND	STMTNMBR	000073	1				SUBROUTINE ASCMIE
140L	USRDEFND	STMTNMBR	000107	1				SUBROUTINE ASCMIE
141L	USRDEFND	STMTNMBR	000134	1				SUBROUTINE ASCMIE
150L	USRDEFND	STMTNMBR	000141	1				SUBROUTINE ASCMIE
160L	USRDEFND	STMTNMBR	000223	1				SUBROUTINE ASCMIE
200L	USRDEFND	STMTNMBR	000227	1				SUBROUTINE ASCMIE
201L	USRDEFND	STMTNMBR	000350	1				SUBROUTINE ASCMIE
210L	USRDEFND	STMTNMBR	000354	1				SUBROUTINE ASCMIE
211L	USRDEFND	STMTNMBR	000417	1				SUBROUTINE ASCMIE
212L	USRDEFND	STMTNMBR	000440	1				SUBROUTINE ASCMIE
220L	USRDEFND	STMTNMBR	000441	1				SUBROUTINE ASCMIE
230L	USRDEFND	STMTNMBR	000664	1				SUBROUTINE ASCMIE
231L	USRDEFND	STMTNMBR	001001	1				SUBROUTINE ASCMIE
240L	USRDEFND	STMTNMBR	001002	1				SUBROUTINE ASCMIE
300L	USRDEFND	STMTNMBR	001025	1				SUBROUTINE ASCMIE
302L	USRDEFND	STMTNMBR	001134	1				SUBROUTINE ASCMIE
310L	USRDEFND	STMTNMBR	001135	1				SUBROUTINE ASCMIE
320L	USRDEFND	STMTNMBR	001311	1				SUBROUTINE ASCMIE
330L	USRDEFND	STMTNMBR	001403	1				SUBROUTINE ASCMIE
331L	USRDEFND	STMTNMBR	001574	1				SUBROUTINE ASCMIE
340L	USRDEFND	STMTNMBR	001577	1				SUBROUTINE ASCMIE
350L	USRDEFND	STMTNMBR	001606	1				SUBROUTINE ASCMIE
351L	USRDEFND	STMTNMBR	001620	1				SUBROUTINE ASCMIE
400L	USRDEFND	STMTNMBR	001632	1				SUBROUTINE ASCMIE
402L	USRDEFND	STMTNMBR	001720	1				SUBROUTINE ASCMIE
410L	USRDEFND	STMTNMBR	001722	1				SUBROUTINE ASCMIE
500L	USRDEFND	STMTNMBR	001740	1				SUBROUTINE ASCMIE
510L	USRDEFND	STMTNMBR	001741	1				SUBROUTINE ASCMIE
600L	USRDEFND	STMTNMBR	001761	1				SUBROUTINE ASCMIE
9100F	FORMAT	STMTNMBR	000052	4				SUBROUTINE ASCMIE
9110F	FORMAT	STMTNMBR	000064	4				SUBROUTINE ASCMIE
9120F	FORMAT	STMTNMBR	000100	4				SUBROUTINE ASCMIE
9130F	FORMAT	STMTNMBR	000110	4				SUBROUTINE ASCMIE
9140F	FORMAT	STMTNMBR	000142	4				SUBROUTINE ASCMIE
9150F	FORMAT	STMTNMBR	000161	4				SUBROUTINE ASCMIE
9151F	FORMAT	STMTNMBR	000176	4				SUBROUTINE ASCMIE
9600F	FORMAT	STMTNMBR	000206	4				SUBROUTINE ASCMIE
A	COMPLEX	ARRAY	000000	0	16	7000		SUBROUTINE ASCMIE
AN	COMPLEX	SCALAR	071731	0	16			SUBROUTINE ASCMIE
ANP	COMPLEX	SCALAR	071721	0	16			SUBROUTINE ASCMIE
BN	COMPLEX	SCALAR	071725	0	16			SUBROUTINE ASCMIE
BNP	COMPLEX	SCALAR	071715	0	16			SUBROUTINE ASCMIE
CSTHET	REAL	ARRAY	067722	0	8	100		SUBROUTINE ASCMIE
CTBRQS	REAL	SCALAR	DUMMY		8			SUBROUTINE ASCMIE
ENDSUM	LOGICAL	SCALAR	066571	0	4			SUBROUTINE ASCMIE
FMX	REAL	ARRAY	DUMMY		8	800		SUBROUTINE ASCMIE
I	INTEGER	SCALAR	066540	0	4			SUBROUTINE ASCMIE
J	INTEGER	SCALAR	066541	0	4			SUBROUTINE ASCMIE
K	REAL	SCALAR	DUMMY		8			SUBROUTINE ASCMIE

NAME	TYPE	MODE	RELATIVE ADDRESS	LOC COUNT	ELEMENT LENGTH	NUMBER OF ELEMENTS	COMMON SIZE	PROGRAM UNIT
KK	INTEGER	SCALAR	070552	0	4			SUBROUTINE ASCMIE
M	COMPLEX	SCALAR	066543	0	16			SUBROUTINE ASCMIE
MI	COMPLEX	SCALAR	070553	0	16			SUBROUTINE ASCMIE
N	REAL	SCALAR	DUMMY		8			SUBROUTINE ASCMIE
NMX1	INTEGER	SCALAR	071713	0	4			SUBROUTINE ASCMIE
NMX2	INTEGER	SCALAR	071714	0	4			SUBROUTINE ASCMIE
NN	INTEGER	SCALAR	070557	0	4			SUBROUTINE ASCMIE
NN1	INTEGER	SCALAR	066542	0	4			SUBROUTINE ASCMIE
NTHETA	INTEGER	SCALAR	DUMMY		4			SUBROUTINE ASCMIE
PI	REAL	ARRAY	070560	0	8	300		SUBROUTINE ASCMIE
QEXT	REAL	SCALAR	DUMMY		8			SUBROUTINE ASCMIE
QSCAT	REAL	SCALAR	DUMMY		8			SUBROUTINE ASCMIE
SI2THT	REAL	ARRAY	070242	0	8	100		SUBROUTINE ASCMIE
STOP	LOGICAL	SCALAR	071710	0	4			SUBROUTINE ASCMIE
T	REAL	ARRAY	066547	0	8	5		SUBROUTINE ASCMIE
TA	REAL	ARRAY	071735	0	8	4		SUBROUTINE ASCMIE
TAU	REAL	ARRAY	066572	0	8	300		SUBROUTINE ASCMIE
TB	REAL	ARRAY	071731	0	8	2		SUBROUTINE ASCMIE
TC	REAL	ARRAY	071725	0	8	2		SUBROUTINE ASCMIE
TC1	COMPLEX	SCALAR	066561	0	16			SUBROUTINE ASCMIE
TC2	COMPLEX	SCALAR	066565	0	16			SUBROUTINE ASCMIE
TD	REAL	ARRAY	071721	0	8	2		SUBROUTINE ASCMIE
TE	REAL	ARRAY	071715	0	8	2		SUBROUTINE ASCMIE
THETAD	REAL	ARRAY	DUMMY		8	100		SUBROUTINE ASCMIE
WM1	COMPLEX	SCALAR	070232	0	16			SUBROUTINE ASCMIE
WN	COMPLEX	ARRAY	071735	0	16	2		SUBROUTINE ASCMIE
X	REAL	SCALAR	DUMMY		8			SUBROUTINE ASCMIE
XI	REAL	SCALAR	071711	0	8			SUBROUTINE ASCMIE
XMI	COMPLEX	SCALAR	070236	0	16			SUBROUTINE ASCMIE

```
ENTRY POINTS
ASCMIE              ENTRY     000016        1

EXTERNAL REFERENCES
IBJ$        BDICALL$    BDIREF$     ASCMIE      FMTC$$      FMTE$$      F2SE$$      DSQRT       FSTOP$      FDCDV$
DCOS        DSIN

END FTN 1015 IBANK 29981 DBANK

@RESUME.H
```

APPENDIX B

FTN COMPILATION LISTING OF MAIN PROGRAM MIECHK

```
@FTN.DRSZ CLASS.MIECHK
FTN 8R   *11/24/80-12:51(8.)
              DOUBLE PRECISION RFR,RFI,X,QEXT,QSCAT,QABS,THETD(100),AJX,
             1                 ELTRMX(4,100,2),ALAM,CTBRQS,AVCSTH,
             2                 CON/3.1415926535897932D0/
              REAL AIN(100,2),POLR(100,2)
           90 READ(5,10,END=1000) RFR,RFI,X,JX,AJX,MMM
              READ(5,12) THETD(1)
              IF( MMM .EQ. 0 ) GO TO 95
        C     IF MMM = 0,THE VALUE OF X REMAINS UNCHANGED,OTHERWISE,X IS
        C     CHANGED TO ( 2.0 * PI * X ) / ( MMM * 1.0D-3 ).
              ALAM = MMM * 1.0D-3
              X = (2.0D0 * CON * X) / ALAM
           95 DO 100 J = 2,JX
1             THETD(J) = (J - 1) * AJX + THETD(1)
1         100 CONTINUE
              CALL ASCMIE( X,RFR,RFI,THETD,JX,QEXT,QSCAT,CTBRQS,ELTRMX )
              QABS = QEXT - QSCAT
              AVCSTH = CTBRQS / QSCAT
              DO 150 K = 1,2
1             DO 150 J = 1,JX
2             AIN(J,K) = ELTRMX(1,J,K) + ELTRMX(2,J,K)
2             POLR(J,K) = ( ELTRMX(2,J,K) - ELTRMX(1,J,K) ) / AIN(J,K)
2             AIN(J,K) = 0.5 * AIN(J,K)
2         150 CONTINUE
              WRITE(6,20)
              WRITE(6,25) X
              WRITE(6,30) RFR,RFI
              WRITE(6,35)
              WRITE(6,40) (THETD(J),(ELTRMX(I,J,1),I= 1,4),AIN(J,1),POLR(J,1),
             1J = 1,JX)
              DO 200 J = 1,JX
1             THETD(J) = 180.0D0 - THETD(J)
1         200 CONTINUE
              JMX = JX - 1
              DO 210 J = 1,JMX
1             JJ = JX - J
1             WRITE(6,40) THETD(JJ),(ELTRMX(I,JJ,2),I = 1,4),
1            1            AIN(JJ,2),POLR(JJ,2)
1         210 CONTINUE
              WRITE(6,45) QEXT
              WRITE(6,50) QSCAT
              WRITE(6,55) QABS
              WRITE(6,60) AVCSTH
              WRITE(6,20)
              GO TO 90
         1000 STOP
        C
        C     FORMAT STATEMENTS FOR MIECHK
        C
           10 FORMAT()
           12 FORMAT(D15.5)
           20 FORMAT('1')
           25 FORMAT('0',10X,'ELEMENTS OF THE TRANSFORMATION MATRIX FOR A SPHERE
             1 WITH SIZE PARAMETER = ',F15.5)
```

```
30 FORMAT('0'.10X.'REFRACTIVE INDEX. REAL = '.D15.5. 0X.'IMAGINARY ='
  1D15.5//)
35 FORMAT('0'.2X.'ANGLE'.9X.'M SUB 2'.5X.' M SUB 1'.8X.' S SUB 21'.6X
  1.'D SUB 21'.8X.'INTENSITY'.6X.'POLARIZATION'//)
40 FORMAT(F10.4.5E15.6.F15.4)
45 FORMAT('0'.9X.' EFFICIENCY FACTOR FOR EXTINCTION'.E15.6)
50 FORMAT('0'.9X.' EFFICIENCY FACTOR FOR SCATTERING'.E15.6)
55 FORMAT('0'.9X.' EFFICIENCY FACTOR FOR ABSORPTION'.E15.6)
60 FORMAT('0'.9X.' ASYMMETRY FACTOR',E15.6//)
   END
```

F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G

MAIN PROGRAM

NAME	USE	LINE NUMBER			
10	DEFINED	49			
	USED	5			
12	DEFINED	50			
	USED	6			
20	DEFINED	51			
	USED	24	43		
25	DEFINED	52			
	USED	25			
30	DEFINED	54			
	USED	26			
35	DEFINED	56			
	USED	27			
40	DEFINED	58			
	USED	28	36		
45	DEFINED	59			
	USED	39			
50	DEFINED	60			
	USED	40			
55	DEFINED	61			
	USED	41			
60	DEFINED	62			
	USED	42			
90	DEFINED	5			
	USED	44			
95	DEFINED	12			
	USED	7			
100	DEFINED	14			
	USED	12			
150	DEFINED	23			
	USED	18	19		
200	DEFINED	32			
	USED	30			
210	DEFINED	38			
	USED	34			
1000	DEFINED	45			
	USED	5			
AIN	SPEC	4			
	SET	20	22		
	USED	21	22	28	36
AUX	SPEC	1			
	SET	5			
	USED	13			
ALAM	SPEC	1			
	SET	10			
	USED	11			
ASCMIE	USED	15			
AVCSTH	SPEC	1			
	SET	17			
	USED	42			
CON	SPEC	1			
	SET	1			
	USED	11			

CTBRQS	SPEC	1							
	USED	15	17						
ELTRMX	SPEC	1							
	USED	15	20	20	21	21	28	36	
I	SET	28	28	36	36				
	USED	28	36						
J	SET	12	12	19	19	28	28	30	30
		34	34						
	USED	13	13	20	20	20	21	21	21
		21	22	22	28	28	28	28	31
		31	35						
JJ	SET	35							
	USED	36	36	36	36				
JMX	SET	33							
	USED	34							
JX	SET	5							
	USED	12	15	19	28	30	33	35	
K	SET	18	18						
	USED	20	20	20	21	21	21	21	22
		22							
MMM	SET	5							
	USED	7	10						
POLR	SPEC	4							
	SET	21							
	USED	28	36						
QABS	SPEC	1							
	SET	16							
	USED	41							
QEXT	SPEC	1							
	USED	15	16	39					
QSCAT	SPEC	1							
	USED	15	16	17	40				
RFI	SPEC	1							
	SET	5							
	USED	15	26						
RFR	SPEC	1							
	SET	5							
	USED	15	26						
THETD	SPEC	1							
	SET	6	13	31					
	USED	13	15	28	31	36			
X	SPEC	1							
	SET	5	11						
	USED	11	15	25					

F O R T R A N   S T O R A G E   M A P

NAME	TYPE	MODE	RELATIVE ADDRESS	LOC COUNT	ELEMENT LENGTH	NUMBER OF ELEMENTS	COMMON SIZE	PROGRAM UNIT
10F	FORMAT	STMTNMBR	000005	4				MAIN PROGRAM
12F	FORMAT	STMTNMBR	000006	4				MAIN PROGRAM
20F	FORMAT	STMTNMBR	000010	4				MAIN PROGRAM
25F	FORMAT	STMTNMBR	000012	4				MAIN PROGRAM
30F	FORMAT	STMTNMBR	000040	4				MAIN PROGRAM
35F	FORMAT	STMTNMBR	000057	4				MAIN PROGRAM
40F	FORMAT	STMTNMBR	000107	4				MAIN PROGRAM
45F	FORMAT	STMTNMBR	000113	4				MAIN PROGRAM
50F	FORMAT	STMTNMBR	000127	4				MAIN PROGRAM
55F	FORMAT	STMTNMBR	000143	4				MAIN PROGRAM
60F	FORMAT	STMTNMBR	000157	4				MAIN PROGRAM
90L	USRDEFND	STMTNMBR	000004	1				MAIN PROGRAM
95L	USRDEFND	STMTNMBR	000026	1				MAIN PROGRAM
100L	USRDEFND	STMTNMBR	000044	1				MAIN PROGRAM
150L	USRDEFND	STMTNMBR	000110	1				MAIN PROGRAM
200L	USRDEFND	STMTNMBR	000142	1				MAIN PROGRAM
210L	USRDEFND	STMTNMBR	000171	1				MAIN PROGRAM
1000L	USRDEFND	STMTNMBR	000215	1				MAIN PROGRAM
AIN	REAL	ARRAY	003745	0	4	200		MAIN PROGRAM
AJX	REAL	SCALAR	004255	0	8			MAIN PROGRAM
ALAM	REAL	SCALAR	000323	0	8			MAIN PROGRAM
AVCSTH	REAL	SCALAR	000311	0	8			MAIN PROGRAM
CON	REAL	SCALAR	004261	0	8			MAIN PROGRAM
CTBRQS	REAL	SCALAR	004263	0	8			MAIN PROGRAM
ELTRMX	REAL	ARRAY	000325	0	8	800		MAIN PROGRAM
I	INTEGER	SCALAR	000313	0	4			MAIN PROGRAM
J	INTEGER	SCALAR	000314	0	4			MAIN PROGRAM
JJ	INTEGER	SCALAR	003741	0	4			MAIN PROGRAM
JMX	INTEGER	SCALAR	000310	0	4			MAIN PROGRAM
JX	INTEGER	SCALAR	003744	0	4			MAIN PROGRAM
K	INTEGER	SCALAR	000315	0	4			MAIN PROGRAM
MMM	INTEGER	SCALAR	000320	0	4			MAIN PROGRAM
POLR	REAL	ARRAY	003425	0	4	200		MAIN PROGRAM
QABS	REAL	SCALAR	004257	0	8			MAIN PROGRAM
QEXT	REAL	SCALAR	000316	0	8			MAIN PROGRAM
QSCAT	REAL	SCALAR	003742	0	8			MAIN PROGRAM
RFI	REAL	SCALAR	003735	0	8			MAIN PROGRAM
RFR	REAL	SCALAR	003737	0	8			MAIN PROGRAM
THETD	REAL	ARRAY	000000	0	8	100		MAIN PROGRAM
X	REAL	SCALAR	000321	0	8			MAIN PROGRAM

ENTRY POINTS

FMAINS		ENTRY	000000	1

EXTERNAL REFERENCES

```
IBJ$        BDICALL$    BDIREF$     FMAIN$      FINIT$      FMTES$      F2SES$      ASCMIE      FMTCS$      FSTOP$
FEXIT$

END FTN 144 IBANK 2526 DBANK

@RESUME.H
```

APPENDIX C

MAP LISTING OF ABSOLUTE ELEMENT ASCMIE

```
@MAP.S .CLASS.ASCMIE
MAP 30R1 S74T11 11/24/80 12:52:54
    1.          IN CLASS.MIECHK
    2.          IN CLASS.ASCMIE
    3.          LIB FTN.
    4.           END

AFCM STATUS OF OUTPUT ELEMENT=UNKNOWN
QUARTER-WORD SENSITIVE

ADDRESS LIMITS    001000 004037      1568 IBANK WORDS DECIMAL
                  040000 142645     34214 DBANK WORDS DECIMAL
STARTING ADDRESS  001631


               SEGMENT $MAINS          001000 004037     040000 142645

ERUS/EWAFIX                                                                16 MAY 80    13:02:38
M$PKTS                                           $(2)      040000 040011   20 NOV 78    17:09:58
F2RTRNS                                          $(2)      040012 040013   16 AUG 77    16:22:24
F2ACTIV$/FORFTN          $(1)     001000 001013  $(2)      040014 040016   12 JAN 78    11:01:29
                         $(3)     001014 001027
                         $(5)     001030 001030
F2TABX                                           $(2)      040017 040330   26 JUN 75    13:29:39
F2FCA                                            $(0)      040331 040335   03 JAN 75    07:43:40
FORCOM$/FORFTN                                   $(2)      040336 040343   23 JUL 75    12:16:44
F2CLOSE                  $(1)     001031 001062  $(0)      040344 040346   12 JAN 79    12:22:37
CERUS                                                                      24 AUG 76    16:59:09
PMD$COM(COMMONBLOCK)                                       040347 040347
F2CON                                            $(2)      040350 042224   12 JAN 79    12:22:50
                                                 $(034)    MOEROS
                                                 $(036)    PMD$COM
F2FRT                                            $(034)    042225 042266   27 JUL 78    12:58:44
MEMINTERFACE             $(1)     001063 001165  $(2)      042267 042314   20 NOV 78    17:10:37
F2SCT                                            $(2)      042315 042616   20 NOV 78    17:06:44
F2INIT                                           $(2)      042617 042776   12 JAN 79    12:23:57
F2CDCD$                                          $(2)      042777 043044   19 DEC 74    14:35:02
F2EXIT                                           $(2)      043045 043100   12 JAN 79    12:23:10
F2IDENT                                                                    04 MAY 78    15:34:26
CDDIV$/MATH              $(1)     001166 001365  $(2)      043101 043127   18 NOV 76    16:44:46
                         $(037)   INFO-010-LC    $(034)    MOEROS
DSINCOS$/MATH            $(1)     001366 001556  $(2)      043130 043225   18 NOV 76    16:42:52
                         $(037)   INFO-010-LC    $(034)    MOEROS
MOEROS(COMMONBLOCK)                                        043226 043231
DSQRT$/MATH              $(1)     001557 001630  $(2)      043232 043252   18 NOV 76    16:42:59
                         $(037)   INFO-010-LC    $(034)    MOEROS
MIECHK                   $(1)     001631 002050  $(0)      043253 047537   24 NOV 80    12:51:38
                                                 $(4)      047540 050155
                                                 $(6)      050156 050170
                                                 $(012)    050171 050210
ASCMIE                   $(1)     002051 004037  $(0)      050211 142155   24 NOV 80    10:54:37
                                                 $(4)      142156 142556
```

```
                                                   $(6)      142557 142611
                                                   $(012)    142612 142645

COMMON BANKS REFERENCED

  0400036  0400003  0400025  0400002  0400001
SYS$*RLIB$. LEVEL 74R1
END MAP.  ERRORS: 0  TIME: 12.263  STORAGE: 13696/3/030777/073777

@RESUME.H
```

APPENDIX D

SAMPLE OUTPUT FROM EXECUTION OF ABSOLUTE ELEMENT ASCMIE

ELEMENTS OF THE TRANSFORMATION MATRIX FOR A SPHERE WITH SIZE PARAMETER = 1570.79600

REFRACTIVE INDEX. REAL = .13420+001 IMAGINARY = .10000+000

ANGLE	M SUB 2	M SUB 1	S SUB 21	D SUB 21	INTENSITY	POLARIZATION
.0000	.154427+013	.154427+013	.154427+013	.000000	.154427+013	.0000
1.0000	.191006+009	.191972+009	.191488+009	.210217+006	.191489+009	.0025
2.0000	.147108+008	.150618+008	.148805+008	-.376900+006	.148863+008	.0118
3.0000	.128131+007	.158656+007	.142506+007	-.455865+005	.143393+007	.1064
4.0000	.199123+007	.226270+007	.212165+007	.646080+005	.212696+007	.0638
5.0000	.200562+007	.222034+007	.211025+007	-.336779+004	.211298+007	.0508
6.0000	.104769+007	.122670+007	.113278+007	-.447543+005	.113720+007	.0787
7.0000	.533631+006	.705286+006	.613227+006	-.177689+005	.619459+006	.1386
8.0000	.550585+006	.719071+006	.629207+006	.298957+004	.634828+006	.1327
9.0000	.557855+006	.716762+006	.632268+006	-.929962+004	.637308+006	.1247
10.0000	.422135+006	.573725+006	.491758+006	-.190622+005	.497930+006	.1522
11.0000	.327684+006	.478442+006	.395779+006	-.116908+005	.403063+006	.1870
12.0000	.318546+006	.469145+006	.385519+006	-.688259+004	.393845+006	.1912
13.0000	.301075+006	.449385+006	.367652+006	-.114045+005	.375230+006	.1976
14.0000	.256418+006	.403351+006	.321327+006	-.132425+005	.329884+006	.2227
15.0000	.228798+006	.376102+006	.293164+006	-.103056+005	.302450+006	.2435
16.0000	.217879+006	.365087+006	.281859+006	-.100057+005	.291483+006	.2525
17.0000	.199721+006	.346162+006	.262675+006	-.117313+005	.272941+006	.2683
18.0000	.179548+006	.325754+006	.241581+006	-.112776+005	.252651+006	.2893
19.0000	.167236+006	.313355+006	.228681+006	-.104599+005	.240296+006	.3040
20.0000	.155808+006	.301334+006	.216399+006	-.110323+005	.228571+006	.3183
21.0000	.142512+006	.287390+006	.202072+006	-.111154+005	.214951+006	.3370
22.0000	.131931+006	.276235+006	.190606+006	-.106396+005	.204083+006	.3535
23.0000	.122759+006	.266202+006	.180452+006	-.107497+005	.194480+006	.3688
24.0000	.113108+006	.255539+006	.169669+006	-.107599+005	.184324+006	.3864
25.0000	.104690+006	.246076+006	.160163+006	-.104809+005	.175384+006	.4031
26.0000	.971025+005	.237257+006	.151423+006	-.104550+005	.167180+006	.4192
27.0000	.896180+005	.228419+006	.142700+006	-.103483+005	.159019+006	.4364
28.0000	.820251+005	.220303+006	.134780+006	-.101477+005	.151614+006	.4531
29.0000	.766734+005	.212492+006	.127245+006	-.100567+005	.144583+006	.4697
30.0000	.707459+005	.204929+006	.120001+006	-.988153+004	.137837+006	.4867
31.0000	.653489+005	.197216+006	.113202+006	-.971707+004	.131564+006	.5034
32.0000	.602428+005	.190914+006	.106816+006	-.956611+004	.125578+006	.5203
33.0000	.555177+005	.184339+006	.100728+006	-.937711+004	.119928+006	.5371
34.0000	.511188+005	.178027+006	.940507+005	-.921292+004	.114573+006	.5538
35.0000	.470068+005	.171957+006	.894524+005	-.902452+004	.109482+006	.5706
36.0000	.431974+005	.166150+006	.842556+005	-.884465+004	.104674+006	.5873
37.0000	.396331+005	.160557+006	.793025+005	-.865717+004	.100096+006	.6040
38.0000	.363354+005	.155193+006	.746154+005	-.846993+004	.957668+005	.6206
39.0000	.332576+005	.150041+006	.701529+005	-.828110+004	.916492+005	.6371
40.0000	.304033+005	.145093+006	.659229+005	-.809161+004	.877481+005	.6535
41.0000	.277480+005	.140333+006	.618991+005	-.790212+004	.840403+005	.6698
42.0000	.252864+005	.135761+006	.580811+005	-.771314+004	.805238+005	.6860
43.0000	.230011+005	.131364+006	.544509+005	-.752451+004	.771826+005	.7020
44.0000	.208847+005	.127130+006	.510040+005	-.733765+004	.740115+005	.7178
45.0000	.189241+005	.123074+006	.477277+005	-.715150+004	.709992+005	.7335
46.0000	.171109+005	.119166+006	.446150+005	-.696781+004	.681387+005	.7489

47.0000	.154354+005	.115409+006	.416573+005	[illegible]	.65[illegible]217+005	.7641
48.0000	.136838+005	.111792+006	.386462+005	[illegible]	.624061+005	.7790
49.0000	.124634+005	.108315+006	.361751+005	-.642557+004	.603893+005	.7956
50.0000	.111511+005	.104968+006	.336363+005	-.625375+004	.582597+005	.8079
51.0000	.994507+004	.101748+006	.312235+005	-.608182+004	.558469+005	.8219
52.0000	.833859+004	.986499+005	.289304+005	-.591273+004	.537442+005	.8355
53.0000	.782527+004	.956676+005	.267507+005	-.574659+004	.517465+005	.8488
54.0000	.689926+004	.927970+005	.246790+005	-.558359+004	.498481+005	.8616
55.0000	.605504+004	.900335+005	.227099+005	-.51237[illegible]+004	.480443+005	.8740
56.0000	.529735+004	.873728+005	.208381+005	-.526710+004	.463301+005	.8859
57.0000	.459133+004	.848107+005	.190590+005	-.511372+004	.447010+005	.8973
58.0000	.396239+004	.823433+005	.173677+005	-.496365+004	.431528+005	.9082
59.0000	.339620+004	.799668+005	.157601+005	-.481688+004	.416815+005	.9185
60.0000	.288872+004	.776775+005	.142319+005	-.467344+004	.402831+005	.9283
61.0000	.243613+004	.754720+005	.127792+005	-.453333+004	.389541+005	.9375
62.0000	.203486+004	.733469+005	.113983+005	-.439654+004	.376909+005	.9460
63.0000	.168155+004	.712991+005	.100356+005	-.426306+004	.364903+005	.9539
64.0000	.137304+004	.693254+005	.883776+004	-.413286+004	.353492+005	.9612
65.0000	.110636+004	.674229+005	.765157+004	-.400592+004	.342646+005	.9677
66.0000	.878718+003	.655888+005	.652400+004	-.388220+004	.332338+005	.9736
67.0000	.687495+003	.638204+005	.545216+004	-.376167+004	.322540+005	.9787
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